THE CULTURE OF CHANNEL CATFISH, Ictalurus punctatus (Rafinesque), IN CAGES SUSPENDED IN PONDS

H. R. SCHMITTOU

Auburn University Agricultural Experiment Station, Auburn, Alabama

ABSTRACT

Since 1966,[1] a study has been conducted in earthen ponds of the Auburn University Agricultural Experiment Station, Auburn, Alabama, to evaluate the potential of suspended cages for culturing catfish, *Ictalurus punctatus* (Rafinesque), from fingerlings to marketable size, and to develop the basic techniques necessary for the extension of the culture. This paper presents the developments obtained in the study. Experiments on effects of stocking density per volume of cage, cage positioning relative to the environment and to other cages, and cage mesh size on production are discussed. Observations on feeding behavior, feeding enclosures, feed efficiency, cage materials, cage covers, parasites and disease and other aspects of cage culture are discussed to a limited extent.

Stocking densities tested ranged up to 500 fish per m^3 of cage. The highest standing crop produced was 421 lb. per m^3 cage stocked with 500 fish. In a 40-day period these fish grew from a mean weight of 0.43 lb. to a mean weight of 0.83 lb. The mean weight gained per m^3 cage per day was 4.94 lb.; feed conversion was 1.34 using floating pelleted feed.

Cage positions in ponds relative to other cages and to exposure to wind induced water currents of open water were found to have an effect on production of fish in those cages. Cages enclosed with 0.25-inch mesh hardware cloth were found to be significantly inferior to cages enclosed with 0.50-inch mesh for raising channel catfish. From these and other results, frequency of water exchange was considered to be a major limiting factor in production of channel catfish in cages suspended in ponds.

For all experiments during 1967 and 1968, a net total of 10, 121 lb. of fish was produced with 12,713 lb. of feed for a conversion of 1.25. The lowest mean feed conversion was 1.03 (range of 0.97 to 1.09) among three replications of a treatment stocked at 300 fish per m^3 of cage.

Wood and hardware cloth have certain characteristics that make each undesirable as ultimate cage construction materials. In each of 2 years, approximately 2,000 lb. of channel catfish in cages and 200 to 400 lb. of other fishes in open water were produced per surface acre of pond. Observations indicate that channel catfish in cages are more susceptible to mortalities as a result of low oxygen-high free carbon dioxide concentrations in ponds than tolerated by fishes in open water of those ponds. Indications are that bacterial diseases may be another major limiting factor to the culture of channel catfish in cages suspended in ponds.

INTRODUCTION

Cage culture of fish is defined as the raising of fish from fingerlings to harvestable size in containers (cages) enclosed on all sides and bottom by wooden slats, hardware cloth, net or other materials that allow free circulation of water in and out of the cages. The cages used in this study were suspended in water with approximately 2 to 6 in. of the cage top above the water surface and the cage bottom at least 1 ft. above the water bottom.

---

1 Thomas C. Scott directed the first year's research in cage culture of channel catfish. His work is summarized in the unpublished Fisheries Research Annual Report (1966), Auburn Univesrity Agricultural Experiment Station, Auburn, Alabama.

Raising fish in cages has been practiced in parts of Asia since before the turn of the century (Thiemmedh, 1961), but it has gained little attention outside of local areas within countries of Asia probably due primarily to the lack of adequate feeds. Therefore, cage cultures have been restricted to local areas where water, proteins and other nutrients were available for conversion into fish flesh on the intensive basis required in cage culture. This was principally in the riverine areas of Thailand and Cambodia and the sewage streams of Indonesia.

Now that feeds are available for culturing channel catfish on an intensive basis, culture in suspended cages appears to have potential in advancing the private and commercial channel catfish industry due in part to the following advantages:

1. It may be practiced in many types of water environment such as lakes, reservoirs, swamps, farm ponds, mining pits, irrigation canals, tidal streams, estuaries, bays and coastal waters.
2. It allows for an intensive culture where otherwise only a lower level of culture might be feasible.
3. It allows for a combination of cultures in ponds, such as channel catfish in cages and largemouth bass-bluegill in open water.
4. It allows for closer observation of feeding activity and general health of the fish.
5. It provides for an easier, more economical method for treating for disease and parasites.
6. It allows for an easy and complete harvest by simply lifting the cages from the water.
7. It permits the manipulation of harvest to fit the market: fish in all stages of growth may be cultured simultaneously in the same or separate cages.

This paper presents data on the development to date of culturing channel catfish in cages suspended in ponds of the Auburn University Agricultural Experiment Station. The general objectives of this research were to test the potential of suspended cages for culturing channel catfish from fingerlings to marketable size, and to develop the basic techniques necessary for the extension of this culture. The research project was divided into three areas of study with each having its specific objective. The introduction, materials and methods, and results-discussion for each are presented as separate experiments. In addition, observations pertinent to the development of cage culture are presented.

MATERIALS AND METHODS

The experiments were begun in 1967 in earthen ponds of the Auburn University Agricultural Experiment Station. These ponds are located in Piedmont clay soils approximately 7 mi. north of Auburn, Alabama. A general description of the experimental ponds used for cage culture is presented in Table 1. The cages were constructed of 2 x 2 in. pine or spruce frames enclosed with 0.25 or 0.50 in. galvanized hardware cloth. A total of 92 cages 36 x 47.5 x 36 in. deep (1.32 yd^3 or 1.0 m^3) and six cages 36 x 114 x 39.4 in. deep (3.4 yd^3 or 2.89 m^3) were used in culture. The hardware cloth was attached to the wood frames by steel staples. The wood had not been treated with preservatives. The cages were suspended on the pond surface waters by direct attachment to wooden piers or by flotation with styrofoam or metal canisters. Covers constructed of 2 x 2 in. wooden frames and aluminum sheeting were used on cages of some experiments; others were not covered.

The channel catfish used in the cage experiments were obtained from the Auburn Station, the National Fish Hatchery in Marion, Alabama, and from a private hatchery in Lonoke, Arkansas. The mean sizes of fish stocked per experiment ranged from 0.023 to 0.43 lb. per fish. Before stocking, the fish were held in concrete tanks of approximately 500 gal. capacity with a water flow estimated at 5 to 8 gal. per minute.

Those tanks received from two to five flush treatments with 250 ppm formalin for parasite control.

TABLE 1. General description of experimental ponds used for cage culture of channel catfish from 1967 to 1969

Pond	Surface Acres	Approximate depth (ft.) Maximum	Average
S-3	9.8	12.0	4.0
S-4	1.3	9.5	4.0
S-8	10.7	10.0	4.0
S-16	2.0	7.0	3.0

Any dead fish removed from the cages during the first 7 days following stocking were considered handling mortalities and were replaced. Dead fish removed after the seventh day were not replaced. All dead fish were removed and were weighed or their weight was estimated based on recent sample weights.

The feed used in all tests was a floating feed prepared for trout. It was fed in either of three sizes (approximately 1.5, 4.0 or 6.0 mm) depending upon the size of the fish. Adjustments in feeding rates were made based on the generalized feeding program given in Table 2. The adjustments were made based on periodic samples of fish and expected weight gain from feed consumed during the previous feeding interval. The daily ration for fish of each cage was weighed on an open scoop balance graduated to 0.01 lb. The feed was then transferred to labeled plastic bags for distribution to respective cages.

The floating feed was held in the cages by "feeding rings", rectangular enclosures approximately 12 x 20 x 16 in. deep with the tops and bottoms open. The rings were positioned so that approximately 12 in. of depth of each ring was below the water surface. The rings were constructed of wood, aluminum sheeting, or styrofoam ice chests with the bottoms removed.

At termination of each experiment the cages were pulled ashore and the fish removed by hand-net or dumped directly into tubs by overturning the cages. The fish were counted into plastic tubs and weighed on platform scales of 75 lb. capacity with 1 oz. graduation.

EXPERIMENT I—STOCKING DENSITY

Introduction

An optimum stocking density is the largest number of fish that can be efficiently produced to a harvestable size in a given area or volume of cage. Efficient production refers not necessarily to the maximum weight that can be produced, but rather to the weight that can be produced with a reasonable feed conversion in a reasonable period of time to desired harvestable size. The optimum stocking density per volume of cage, therefore, is dependent upon the water quality of the environment, the weight that can be efficiently produced, the average size fish desired at harvest and the expected mortality.

Various authors have reported stocking densities in cages using common carp, *Cyprinus carpio*, (Vaas and Sachlan, 1957; Kuronuma, 1968; Gribanov et al., 1968) and *Pangasius* catfishes (Aguru;[3] Thiemmedh, 1961); however, the stocking formulas given for the fishes are inconsistent and difficult to compare. Formulas using numbers or weights of fish stocked according to either square (area) or cube (volume) are given. Thiemmedh (1961) reported stocking densities of *Pangasius* catfishes in Thailand to be 113 fish per m^3 (1.3 yd^3) of cage with productions calculated to range from 180 to 240 kg (396 to 528 lb.) per m^3. In a preliminary test by Scott (see page 1) at Auburn University, fingerling channel catfish were stocked in cages having a volume of 1 m^3 at densities of 25, 75, 125 and 175 per cage, and net productions as high as

[3] Mimeograph entitled "The Culture in Cages of Pla-Swai Pangasius sutchi Fowler" by P. Aguru (Department of Fisheries, Ministry of Agriculture, Rajadmnern Avenue, Bangkok, Thailand).

TABLE 2. Generalized feeding program used in the experiments of channel catfish in suspended cages in 1967 an 1968

Culture days	Feeding rate (Per cent of body weight)	Estimated individual fish weight (pounds)		Pounds feed per 100 fish		
		Mean	Range	Per day	Per period	Cumulative
1-30	3.50	0.07	0.05-0.08	0.2	6.0	6.0
31-60	3.00	0.15	0.08-0.20	0.5	15.0	21.0
61-80	2.75	0.25	0.20-0.32	0.7	14.0	35.0
81-100	2.50	0.04	0.32-0.50	1.0	20.0	55.0
101-110	2.25	0.55	0.50-0.60	1.2	12.0	67.0
111-120	2.00	0.65	0.60-0.70	1.3	13.0	80.0
121-130	1.75	0.75	0.70-0.80	1.3	13.0	93.0
131-150	1.50	0.90	0.80-1.00	1.4	28.0	121.0

The original rate of 3.5 per cent was used for fish of 0.05 pound minimum average weight fish weighing less than 0.05 pound average were fed at 4.0 per cent until they attained an average of 0.05 pound each.

121 lb. were obtained. There was no difference (P=.05) in average net gain or feed conversion between densities after 139 days of culture. In that period the fish increased in size from an average 0.12 to 0.81 lb. each. In other studies in 1967 and 1968 on stocking density for cages (Schmittou, 1969), 8,100 white catfish (*Ictalurus catus*) and 3,750 and 4,200 channel catfish were stocked in three separate tests with combined densities ranging from 175 to 425 fish per 1 m^3 cages. Production appeared to be equal at all densities of each test; there were no observed differences or trends in net gain, conversion or survival within tests. However, the mean standing crops per cage at termination ranged from 22.9 to 99.3 lb. between tests, and apparently for density dependent factors to become limiting a greater standing crop, one approaching carrying capacity, is necessary.

The objective of the experiment presented below was to determine the stocking density by which fingerling channel catfish could be efficiently grown to harvestable size (0.8 lb. or larger) in cages suspended in ponds.

Materials and Methods

Channel catfish averaging 0.43 lb. each were stocked into six 1 m^3 cages in pond S-16 on September 7, 1968, at densities of 300, 400 and 500 fish per cage with two replications of each density (2,400 fish). The cages were of 0.50-inch mesh and were positioned 40 in. apart in two batteries of three cages each (Fig. 1). The cages were nailed together in a line suspended by flotation. The two batteries were 20 ft. apart and were in open water approximately 40 ft. from and perpendicular to the dam in water 5 to 6 ft. deep. The experiment was terminated on October 17, after 40 feeding days.

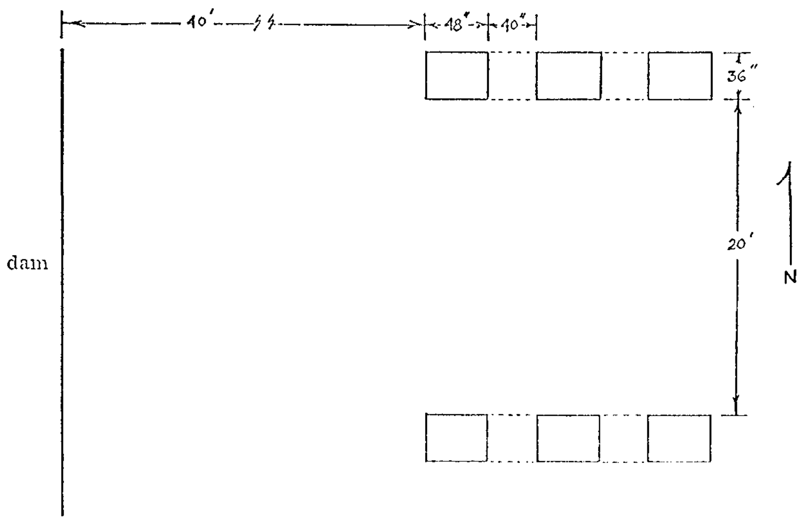

Fig. 1. Position of Cages for Culturing Channel Catfish in Pond S-16 in 1968

Results and Discussion

The production parameters for this experiment are summarized in Table 3. The mean weight increase per cage ranged from 126.5 lb. in cages stocked with 300 fish each to 197.6 lb. in cages stocked with 500 fish each. This was a net gain per 100 fish of 42.2 and 39.5 lb., respectively. The mean weight increase per fish among all treatments was 0.40 lb. (from 0.43 to 0.83 lb.) for an average gain of 0.01 lb. per fish per day. This represents an average daily increase of 4.94 lb. of fish per cage stocked with 500 fish each. Mean feed conversion was 1.30 between treatments and means within treatments ranged from 1.26 among 300 fish per cage to 1.34 among cages with 500 fish each.

Standing crops in the two cages with 500 fish each were 415.2 and 420.9 lb. at termination of the experiment. There was no indication from the production parameters that the growth rate of the fish had decreased in any cage. This indicates that the 415- and 421-lb. standing crops were not at maximum carrying capacity.

This experiment demonstrated that channel catfish could be grown from an initial weight of 0.43 lb. to a final weight of 0.83 lb. in 40 days when stocked at a density of 500 fish per cage in m^3 cages. Also, it was demonstrated that standing crops in excess of 400 lb. per m^3 of cage could be produced. Since maximum carying capacity of the cages was apparently not reached, more than 500 fish could have probably been stocked per m^3 cage, and yet produced fish 0.8 lb. or larger.

TABLE 3. Summary of results of stocking channel catfish at three densities in cages in pond S-16 during 1968

Item	Stocking Density			
	300	400	500	Mean
Standing crop (pounds)	254.0	334.1	418.0	335.3
Net gain (pounds)	126.5	164.4	197.6	162.8
Net gain per 100 fish	42.2	41.1	39.5	40.7
Feed conversion	1.26	1.29	1.34	1.30
Per cent survival	99.6	99.2	99.5	99.4

EXPERIMENT II—CAGE POSITION

Introduction

Determining how closely cages may be placed to each other, to the shore or to another object without affecting production is of importance in developing cage culture in ponds. One may logically assume that the ideal cage placement would be in open water far enough away from other cages and obstacles to allow free water circulation especially from wind induced currents.

The objectives of this experiment were to determine the relative effects on channel catfish production of: (1) cages placed in different positions in relation to each other, and (2) cages placed in different positions in relation to exposure to natural convection currents. The experiment was conducted in two separate tests in separate ponds during 1968.

TEST 1

Materials and Methods

In this test 12 cages 1 m^3 in volume and covered with 0.5-inch mesh were connected into three batteries and positioned in selected locations in pond S-16 in 1968. Each battery consisted of four cages in series with the long sides of the cages parallel and with 32 in. of space between each cage (Fig. 2). The cages were connected by a 10 x 30 in. pine board nailed 3 in. from the top to each end of each cage. Each battery of cages was floated by metal, air-containing cannisters. Each battery was positioned in the pond at the selected location and held in position by nylon cords connecting each end of the battery to concrete block anchors.

The batteries were positioned at locations relative to their exposure to wind-induced water currents, i.e., least exposed, moderately exposed and most exposed (Fig. 3). The batteries were designated A, B and C according to placement. Battery A, in the least exposed location, was

Figures represent two replications of each stocking density.
All cages were 1 m^3 in volume.
Culture period was 40 feeding days.

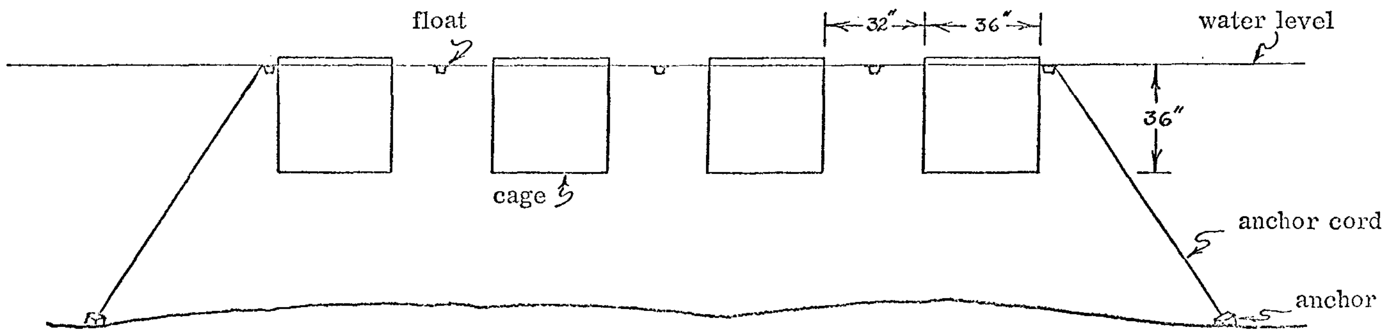

Fig. 2. Battery of Four Cages in Pond S-16 in 1968 Showing Spacing Between Cages, Flotation and Anchors

positioned in a north-south direction outside of a boardwalk, 6 ft. from and parallel to the dam. Battery B was positioned in a southwest to northeast direction 20 ft. from both the dam and the north bank. Battery C, in the most exposed condition, was positioned in a northwest-southeast direction in open water about 70 ft. from the dam.

Strips of 6-ft. deep black polyethylene sheeting, equipped with lead and cork lines to hold them into a vertical position, were used to prevent wind-induced water currents from moving freely through the areas of batteries A and B (Fig. 3). One strip of the plastic was placed between battery A and the boardwalk at a distance of 6 in. from the cages. From each end of battery B, the polyethylene strips stretched toward each bank and also at an oblique angle to the north forming a V-shape with an apex at each end of the battery.

Essentially, the relative placement of the batteries was to have battery A in poor position to benefit from any water currents, for battery B to benefit from water currents induced by winds perpendicular to the prevailing winds, and for battery C to benefit some from all water currents and especially from those induced by the prevailing south-westerly winds.

All cages were stocked on May 9, with 350 channel catfish fingerlings averaging 0.03 lb. each or an average of 10.3 lb. per cage (4,200 fish). The fingerlings were obtained at Lonoke, Arkansas, and had received three flush treatments with 250 ppm formalin for parasite control before stocking.

A total of 159.4 lb. of feed was fed to fish in each cage during a 118-day period from May 10 to September 4. All fish were fed at the same rate per 100 fish. Total weight of feed fed in all cages was 1,912.8 lb. The test terminated on September 6, 120 days after stocking.

Results and Discussion

On September 6, the date of termination of this test, fish of all cages of battery A and two cages of battery B were on the water surface in distress at 8:15 a.m. Fish in battery C and in the pond proper were not on the surface and apparently were not in distress. At 11:30 a.m. near battery A oxygen and free carbon dioxide were 2.0 and 10.0 ppm, respectively, at the surface and 0.5 and 12.5 ppm at 3 ft. Dead fish were recovered only from battery A and there only from the first three cages with only one side toward open water and not in the fourth cage with two sides to open water. The number of dead fish recovered from battery A was 173, 325, 88, and 0 in cages 1 through 4, respectively.

The distress and kill caused by the apparent low oxygen-high carbon dioxide conditions appeared to have been an effect of position. Fish died in three cages of battery A, were in distress in B, and were not observed in distress in C—the order of assumed poorest to best position for fish to benefit from wind-induced water currents.

As the fish were being harvested, the hardware cloth of the cages became detached from the wooden frames enough to allow an unknown number of fish to escape from six cages—three cages of battery A, one from battery B and two from battery C. All dead fish were recovered from A. Data representing fish in these cages were excluded from further consideration in this test. The production results from the other six cages are summarized in Table 4.

The results of net weight gained, feed conversion, and per cent survival indicate a trend of increasing performance from battery A to C with B intermediate in each case. The loss of fish from 6 of 12 cages (replications) prevented a statistical analysis and thus lowered the confidence by which any inference can be made. The greatest difference appears to be in feed conversion and last difference in per cent survival.

TEST 2

Materials and Methods

This test was conducted in pond S-3 in 16 cages 1 m^3 in volume and covered with 0.25-in. mesh hardware cloth. The cages were positioned

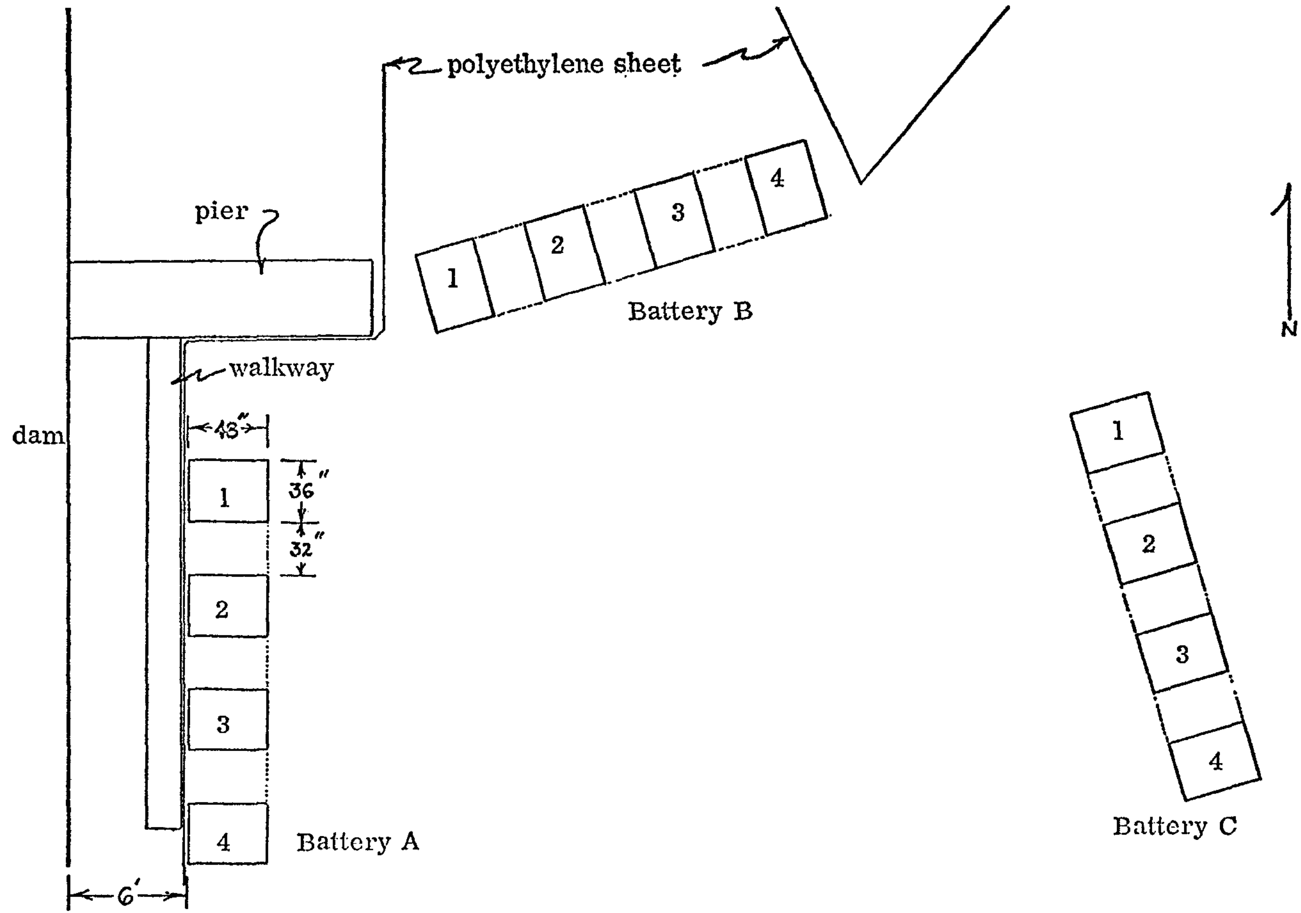

Fig. 3. Position of Batteries of Cages in Pond S-16 in 1968 Showing the Relationship of Each to Exposure to Water Currents.

1 in. apart in a rectangular grid or block of four cages long and four wide (Fig. 4). The individual cages were separated by 1 x 3 in. boards connecting the top edge cage to the adjacent cage. The cages were classified into groups designated as positions I, II, III, and IV according to placement. Each group or position consisted of four cages each. Position I was composed of corner cages with one side and end of each cage exposed to open water. Positions II and III were composed of cages between corners with one side (47.5 in.) or one end (36 in.), respectively, adjacent to open water. Cages of position IV were the middle cages not adjacent to open water. All cages were approximately 2.5 to 3.0 ft. above the pond bottom.

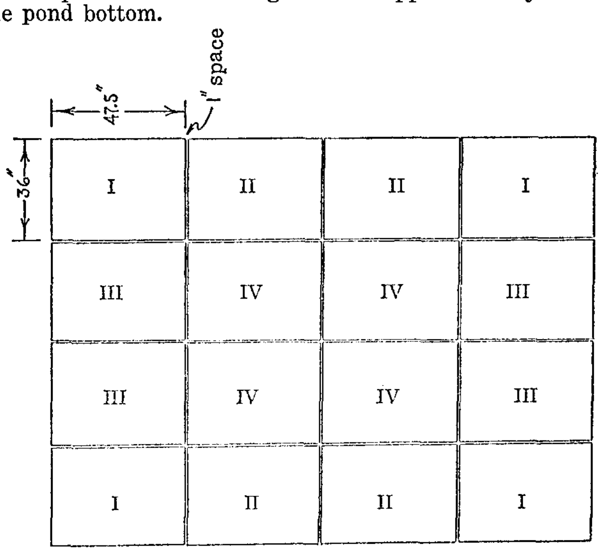

Fig. 4 Position of Cages in S-3 in 1968 Showing the Four Positions (I, II, III and IV) Tested

Channel and white catfish were stocked at densities per cage at 250 and 100, respectively. Channel catfish from Lonoke, Arkansas, averaging 0.03 lb. each, were stocked at 100 per cage in all cages on June 16. The following day 150 channel catfish from the Auburn Station, averaging 0.05 lb. were stocked per cage. White catfish averaging 0.02 lb. were stocked at 100 per cage on June 19.

All fish received two flush treatments with 250 ppm formalin for parasite control before stocking; however, the white catfish were known to be infected with columnaris disease (*Chondrococcus columnaris*) when stocked, but no treatment for the disease was attempted. A total of 20 channel and 95 white catfish were restocked in all cages on or before June 30.

Fish in all cages were fed alike and fish in each cage received a total of 194.4 lb. of feed during the 115 consecutive days of feeding. Total weight of feed used in all cages with 3,110.4 lb.

The test was terminated on October 5, with the harvest of all fish in cages. A statistical comparison for determining significance between treatment means was performed on the net weight gained, feed conversion and per cent survival using the F-test for the analysis of variance and Duncan's multiple range test (Steele and Torrie, 1960).

Results and Discussion

A summary of results of this test is presented in Table 5 and Fig. 5. The mean weight gained ranged from 121.7 lb. in cages of position IV

TABLE 4. Summary of results of culture of channel catfish in cages relative to three positions in Pond S-16 in 1968

Position	Stocked		Recovered		Pounds	Pounds	Feed	Per cent
	Number	Pounds	Number	Pounds	gained	feed	conversion	survival
A	350	10.7	327	140.4	129.7	159.4	1.23	93.4
B	350	10.2	336	145.2	135.0	159.4	1.19	96.0
C	350	10.1	341	156.9	146.8	159.4	1.09	97.5
Mean	350	10.3	335	147.5	137.2	159.4	1.17	95.6

Figures represent one, three, and two replications for positions A, B, and C, respectively.
Culture period was 120 days.
Percent survival includes those fish that died on September 6 as a result of low oxygen—high free carbon dioxide.

TABLE 5. Summary of results of culture of channel catfish in cages relative to four positions in S-3 in 1968

Position	Stocked		Recovered		Pounds gained		Pounds	Feed	Per cent
	Number	Pounds	Number	Pounds	Total	Per 100	feed	conversion	survival
I	350	12.2	253	160.4	148.2	42.3	194.4	1.32	72.3
II	350	12.2	248	148.5	136.3	38.9	194.4	1.43	70.9
III	350	11.9	247	150.0	138.1	39.5	194.4	1.41	70.7
IV	350	11.8	245	133.5	121.7	34.8	194.4	1.61	69.9
Mean	350	12.0	248.	148.0	136.0	38.9	194.4	1.45	709

Figures represent four replications for each position.
Culture period was 115 days.

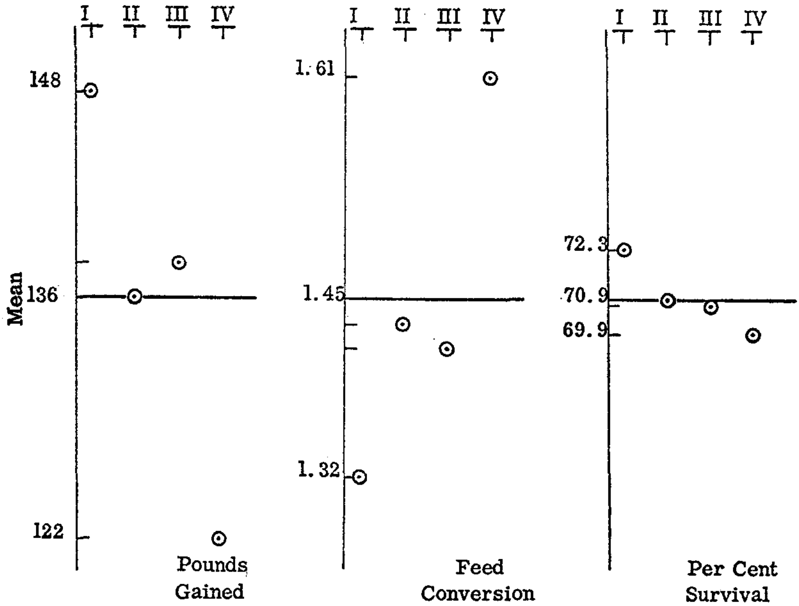

Fig. 5. Comparison of Pounds Gained, Feed Conversion, and Per Cent Survival of Catfish Grown in Cages Relative to Four Positions.

to 148.2 lb. in cages of position I. Feed conversion ranged from 1.61 for fish in position IV to 1.32 for fish in position I. Per cent survival ranged from 69.9 in position IV to 72.3 in position I. From observation it appears that growth, feed conversion and survival were best in cages of position I, were poorest in cages of position IV, and were intermediate in cages of positions II and III. There was no difference (P= .05) between means of either net weight gained, feed conversion or per cent survival using the F-test comparison (Table 6). However, a significant difference (P= .05) was obtained between feed conversion means using Duncan's multiple range test. In this comparison the conversion mean of position I fish was different from conversion means of fish from positions II, III and IV; conversion mean of position IV fish was different from conversion means of fish from positions I, II and III; conversion means of fish from positions II and III were not different from each other. Although there were apparent differences in production parameters between positions tested, 122 lb. of fish were produced per m^3 of cage in the least favorable position for culture (position IV) in 110 days. Also, almost 2,200 lb. was produced in the 16 m^3 space in the 110-day period.

It was concluded from this experiment that channel catfish production in cages was affected by cage position in relation to other cages and to wind-induced water currents. Of the production parameters considered, feed conversion was the most affected. There are two possible reasons for this. First, even though there was no significant difference between treatments in weight gained, weight gained was highest in the most favorably positioned cages and lowest in the least favorable positions. The same amount of feed was fed in each position, which in effect resulted in higher feeding rates in the least favorable positions. The greater amount of feed for fish in the least favorable positions was

TABLE 6. Results of comparisons of pounds gained, feed conversion, and per cent survival of channel catfish in cages relative to four positions

Comparison	Position I	II	III	IV	df	F	Probability .05	.10
Pounds gained	148.2	136.3	138.1	121.7	3/15	2.77	N.S.	*
Feed conversion	1.32	1.43	1.41	1.61	3/15	2.84	N.S.	*
Per cent survival	72.3	70.9	70.7	69.9	3/15	1.70	N.S.	N.S.

apparently in excess of the nutritional needs of the fish. Second, the conditions for feed conversion were poorer in cages in the last favorable positions.

The effect of position is apparently a reflection of water exchange and water quality. The cages with the best production parameters were those with most surface area exposed to water currents. Water exchange must be frequent enough to bring in adequate amounts of dissolved oxygen and to dilute fish produced wastes to a concentration below lethal level and preferably below the level that inhibits growth. Obviously waste concentrations in cages of positions IV (Test 2) were below lethal level, but production performance was inhibited. Since fish in cages of this position were separated from open water by three to five layers of 0.25-in. hardware cloth as well as being surrounded by 5,000 other fish, it is not likely that normal water currents provided much dilution. It is more likely that the primary water exchange was created by the fish themselves. This was certainly the case during periods of no wind. These results indicate that rate or frequency of complete water exchange and its quality is a major limiting factor to cage culture.

EXPERIMENT III—MESH SIZE OF CAGES

Introduction

The objective of this experiment was to determine the effects of mesh size on production of channel catfish in suspended cages.

Materials and Methods

Eight 1 m^3 cages were stocked on April 10, 1969, with 500 channel catfish fingerlings per cage (4,000 fish) that averaged 0.036 lb. per fish. The cages were enclosed with 0.25 and 0.50 in mesh hardware cloth with four cages of each mesh size. The cages were supported by attachment to piers in pond S-3 in water 5 to 7 ft. deep. Fish in each cage were fed a total of 142.4 lb. of feed. Mesh size of the cage used was the only treatment difference between cage populations. The experiment was terminated on July 15, after 93 consecutive days of feeding.

Statistical analyses of the data were made using anlysis of variance with a single criterion of classification (Steel and Torrie, 1960).

Results and Discussion

The production parameters for this experiment are summarized in Table 7. The parameters compared statistically (Table 8) were net gain, average fish size at termination and survival. The mean weight increase per cage was significantly different ($P= .05$) between treatments and ranged from 49.0 lb. per cage in the 0.25 in. mesh cages to 91.8 lb. per cage in the 0.50 in. mesh cages. The mean weight per fish was significantly less ($P= .05$) in the 0.25 in. mesh cages (0.145 lb. average) than in the larger mesh cages (0.232 lb. average). Survival was also significantly less ($P= .10$) in the smaller mesh cages (89%) than in the cages with 0.50 in. mesh (94%).

From these results it was concluded that mesh size was a significant factor in production of channel catfish in cages in ponds. Since no algae or other growth developed on the mesh of cages of either treatment, it was concluded that the difference in production between treatments was directly a result of a differential in frequency or freedom of water circulation through the two meshes. Water exchange was assumed to

TABLE 7. Summary of results of stocking channel catfish into cages of two different mesh sizes in pond S-3 in 1969

Mesh size	Pounds stocked	Pounds recovered	Pounds gained	Average weight recovered fish	% survival	Feed conversion
0.25 in.	17.9	66.9	49.0	0.145 lb.	89.0	2.91
0.50 in.	17.8	109.6	91.8	0.232	94.0	1.55

TABLE 8. Results of Comparisons of Pounds Gained Per Treatment, Average Weight Per Fish at Termination and Per Cent Survival of Channel Catfish in Cages Relative to Mesh Size

Comparison	Treatment (Mesh Size) 0.25 in.	0.50 in.	df	F	Probability .05	.10
Pounds gained	49.0	91.8	1/3	35.26	*	..
Average weight per fish	0.145	0.232	1/3	33.14	*	..
Per cent survival	89.0	94.0	1/3	6.47	N.S.	*

be less frequent in the 0.25 in. mesh cages than in the 0.50 in. mesh cages. As demonstrated in the experiment on cage positioning, these results reflect the limiting effects on production of restricted, insufficient water circulation through the cages.

Feed conversion (i. e., lb. of feed to produce 1.0 lb. of fish) was poor in both treatments averaging 2.91 in the small mesh cages and 1.55 in the 0.50 in. mesh cages. The poor conversion in both treatments was apparently because of excess feeding, resulting from overestimating standing crops when adjusting feeding rates. This was certainly the reason for the poor conversion in the 0.25 in. mesh cages, since both treatments were fed at the same rate.

IV. OBSERVATIONS

INTRODUCTION

The culture of channel catfish in cages had not previously been done prior to the research begun at Auburn in 1966; therefore, observations, particularly those in areas unique to cage culture, must be carefully analyzed when planning further development of the culture. The observations discussed under the following sub-headings were considered pertinent to that development. Each must be subjected to controlled experiment before inferences may be made, but each is discussed in accordance with the implications of the observation.

FEEDS AND FEEDING

Feed efficiency

The relationships between rates of feeding, rates of growth and feed conversions are of major importance in all intensive fish cultures. The more intensive the culture the less natural food that is available to the fish, and in suspended cages the fish are essentially totally dependent upon feed provided by the culturist. The relationship between feeding rate and feed conversion efficiency of channel catfish is dependent on the size of fish, quality and quantity of feed, frequency of feeding and on environmental conditions such as temperature and oxygen-carbon dioxide concentrations. In cages this relationship may also be dependent upon restricted movement of the fish as well as build-up of various wastes inside the cages. Essentially then, feed efficiency is a reflection of the interaction between the fish, the feed and the environment.

The complete nutritional requirements of channel catfish have not yet been determined. Consequently, the adequacy of the diet fed in these experiments was not known. The feed was chosen for use because it was known to be relatively adequate for trout and it was the only floating pelleted feed available at the start of the experiments.

Figures represent averages of four replications of each treatment (mesh size).
Culture period was 93 days.

In all cage experiments during 1967 and 1968 (Schmittou, 1969) a total weight of 10,121 lb. of channel catfish was produced with 12,713 lb. of feed for a 1.25 feed conversion. The lowest conversions obtained were in an experiment where the fish were being fed at a lower rate than normal for all experiments. In one experiment in 1967, 300 fish weighing 107.5 lb. (average of 0.36 lb. per fish) were stocked in a 1 m^3 cage and fed 198.4 lb. of feed over a 59-day period. At the end of that period the 293 fish recovered weighed 287.4 lb. (0.98 lb. average per fish) for a gain of 179.9 lb. Feed conversion was 1.12. In a similar experiment in 1968 three 2.89 m^3 cages were each stocked per m^3 with 300 fingerlings weighing 8.1 lb. (0.027 lb. average) and fed 151.1 lb. of feed during 151 days of culture. At termination the 270 fish recovered per m^3 of cage weighed 155.0 lbs. (0.57 lb. average) for a gain of 146.9 lb. feed conversion was 1.03 and ranged from 0.97 to 1.09 between the three replications.

Feeding Rings

Feeding rings, enclosures to hold the floating feed, were used from the beginning of the project. The first rings were strips of aluminum sheeting about 6 in. wide that were attached to the inside of the cage with the sheet about 2 in. above and 4 in. below the water surface. This allowed the feed to disperse over the entire water surface of the cage. However, this proved unsatisfactory as the fish grew large enough to create water currents when actively feeding that pulled the feed under water and pushed it outside the cage. With this type of feeding ring, feed loss increased as the fish grew. Deepening the ring to a depth necessary to hold the feed, would have affected water exchange in the cage. Therefore, the original feeding rings were replaced by rectangular, topless and bottomless boxes approximately 12 x 20 x 16 in. deep. The rings were positioned near the center of the cages with about 12 in. of the box below the water level. Water currents passed beneath the rings and no feed was lost. These smaller rings may have biased feeding results in favor of the more aggressive fish, but observation did not so indicate.

Feeding Behavior

In the experiment on stocking density (Page 5), 10 lb. per day was being fed into the feeding rings of each of two cages during the last 5 days before termination. The fish, averaging about 0.8 lb. each, had no apparent problem feeding in the 240-$in.^2$ of area within the ring. They congregated below the feeding ring as the person approached to feed. They began feeding immediately and the feed was consumed in less than 2 minutes. As observed in all tests, some fish came up into the rings, took feed and went down, being constantly replaced by other fish until all the feed was consumed. Once the fish began feeding they would feed from a person's hand and even nibble at the person's fingers. After the last pellets had been consumed some fish continued to suck at the water surface creating a sound similar to that made when a person sucks liquid and air through a straw from an almost empty glass.

Feeding behavior was not consistent from day-to-day in any test, and the inconsistency could not always be correlated with anything observed. However, to totally consume the feed, regardless of the amount, usually required from one-half to 2 minutes. If the feed was not consumed within that period, it was usually not eaten for several hours if at all. In such cases feeding was observed to be an index to the well being of the fish. Poor feeding (feed not consumed in less than 2 minutes) was usually associated with disease, oxygen-carbon dioxide stress, recently silted water or falling temperature.

Construction Materials

The wooden framed hardware cloth cages were constructed at a cost of approximately $18 each ($12 to $14 for materials). Preservative treatments for both or either the wood or hardware cloth would increase the cost, but should increase cage longitivity. The untreated cages were usable for two years without repair, and most were satisfactory for a third-year culture with only minor repairs.

The major disadvantage of wooden frames was that they became water-soaked, and, consequently, were undesirably heavy for handling and for floating. A disadvantage of the hardware cloth was in allowing the fish to sustain injury. Also, the cloth tended to rust along the edges where attached to the wood, especially at the staples.

The injury to the fish caused by the hardware cloth was only observed to occur at handling. The injuries were confined to cuts or abraisons around the margins of the mouths of some fish. They were apparently caused by the fish swimming head-on into the hardware cloth. Such injuries could lead to bacterial or fungi infections.

Further testing of cage materials is of paramount importance in order to develop a satisfactory culture cage. Areas of consideration in testing various materials should include economical aspects, durability, longevity and weight.

Cage Covers

Covers over the cages were considered necessary to prevent predation from external sources and to prevent possible loss of fish jumping over the cage edge. However, of possible greater importance of covers was the effect on fish of opaque covering.

For the first few days (1 to 2 weeks) after stocking in cages with open or wire-covered tops, the fish were hyperexcitable and would swim vigorously into the sides of the cage when approached. They would feed only sparingly until the person feeding had moved away from the cage area. From about 2 weeks of culture until the fish averaged near 0.4 to 0.5 lb. each, they were less easily excited than when first stocked, but feeding activity appeared the same. However, when the fish approached 0.5 lb. average weight they became more easily excited than during the 2-week period following stocking, and the fish would not feed for an hour or more after being fed. There was some loss of feed because of the current created by the excited fish.

It was obvious that feed efficiency was being affected as a result of loss of feed and to possible physiological stress. Also, the force by which the fish were swimming into the cage sides was sufficient to cause injury. To lessen or eliminate the problem, aluminum sheeting was attached to the top of each cage. The sheeting covered all the cage top except the space over the feeding ring. It prevented light penetration to the cage interior except for the area within the feeding ring. Within 10 days after attaching the sheeting the fish ceased to swim into the cage sides when approached, and instead, congregated beneath the feeding ring. When fed the fish immediately began feeding even when the person feeding remained by the cage. Tops on cages of all subsequent cultures were equipped with a covering of aluminum sheeting, and the problem with hyperexcitation was not encountered.

Production Per Area of Pond

Carrying capacity for channel catfish in ponds receiving supplemental feed is about 2,400 lb. per acre in this area (Prather and Swingle, 1960). Developments in cage culture of this fish in relation to carrying capacity to total area of pond have thus far been inconclusive. A net of approximately 2,000 lb. of fish per acre has been produced in each of two years in cages suspended in pond S-4 (Table 9). In addition another 200 to 400 net lb. of fishes were produced in the open water each year.

If less weight of fish is going to be possible per acre using cages than with open-pond culture, the limiting factor is probably again going to be frequency of water exchange especially during periods of poor water quality resulting from low oxygen-high free carbon dioxide. This observation is based on three fish kills that occurred in different ponds during 1967 and 1968. The kills, including the one discussed and the experiment on cage positioning (Page 6) occurred in cages during periods of low oxygen-high free carbon dioxide concentrations while no fish in open water showed evidence of distress. Obviously, the fish in open water have an advantage over caged fish during periods of critical gas concentrations. The surface area of the cages used was 1.3 $yd.^2$ each, the surface area per acre of pond was 4,840 $yd.^2$ Catfish stocked at 400 per cage had 0.0033 $yd.^2$ or 4.28 $in.^2$ of water surface area per fish; catfish stocked at 3,000 per acre in open water had 1.61 $yd.^2$ or 2,090.5 $in.^2$ of water surface area per fish. In this comparison each fish in the open water had 485 times as much water surface area as caged fish. During periods of critical gas concentrations the surface water is most likely to contain the highest oxygen and lowest free carbon dioxide concentrations.

TABLE 9. Total Weight of Each Fish Species Produced Per Acre in Cages and Open Water of Pond S-4 in 1967 and 1968

1967

Species	Net pounds produced Cages		Open Water	Total
Largemouth bass	0.0		78.6	78.6
Bluegill	9.7	(2)	2.2	11.9
Tilapia	108.7	(4)	43.5	152.2
White catfish	1,237.9	(34)	318.2	1,556.1
Channel catfish	588.9	(15)	5.3	594.2
Total	1,945.2	(55)	447.8	2,393.0

1968

Species	Cages	Open Water	Total
Striped bass	0.0	73.8	73.8
Fathead minnow	0.0	118.8	118.8
Channel catfish	2,007.3	8.8	2,016.1
Total	2,007.3	201.4	2,208.7

PARASITES AND DISEASE

High densities of fish cultured in cages catagorizes cage culture as having a high potential for fish epizootics. However, certain aspects of cage culture possibly lessen the potential of epizootics as compared to equal or even less densities in other types of fish culture. For instance, fish in suspended cages do not come in contact with the bottom muds that are more likely to have a higher frequency of pathogenic organisms than the surface water. Also, fish feces fall through the cage and are not reconsumed when fish are feeding. In cultures where the fish are loose in the pond, the fish do come in contact with the bottom muds, and are likely to reconsume their own feces as well as that of other fish, especially where sinking feeds are fed at stations around the pond.

Although channel catfish are stocked less densely in the pond proper than in cages, the fish are socially gregarious and often congregate with several hundred fish in a tightly compact school no larger than 4 to 6 ft. in diameter. Apparently this species often feeds in schools, for one method fishermen use for locating channel catfish in nonfed pond populations is to locate patches of bubbles rising to the surface.

No parasite epizootics were encountered in the cage cultures through 1968. The only parasite found in unusually high density was *Henneguya* (Myxosporidia) This protozoan was found encysted in the gills of fish of only one experiment.

Number in parenthesis under cages (1967) represents the total number of cages used in culturing that species.

Disease problems encountered in cage cultures through 1968 have been restricted to columnaris disease caused by myxobacteria *Chron-drococcus columnaris*. This disease was observed in 53 of the total of 98 cages in culture in 1967 and 1968. The intensity of columnaris-caused kills varied between experiments; however, in the experiment where the highest mortality of fish occurred from all causes, (Experiment II, Test 2) the 100 white catfish stocked were known to be infected when stocked. The white catfish apparently infected the channel catfish, and during 110 days in culture, 19.7 per cent of the white catfish and 32.8 per cent of the channel catfish (29.1 per cent of both species) died from columnaris and other causes. No treatment for control of the disease was attempted before or during the culture. The epizootic was chronic and persisted throughout the culture period. The conditions for production were probably less favorable in this test than in any of the other tests, which probably made conditions for a columnaris epizootic the most favorable.

The effects of parasites thus far observed in cage culture of channel catfish indicate that parasites are not of any greater threat to the caged fish than to fish cultured in the pond proper. However, the effects of disease, specifically columnaris disease, indicates that bacterial diseases may be a major limiting factor in the culture of channel catfish in suspended cages in ponds, at least until better, more effective means of treatment are developed.

SUMMARY

1. The advantages of raising channel catfish in suspended cages are such that the private and commercial catfish industries should be advanced.

2. Experiments were conducted in cages suspended in earthen ponds to test the potential of raising channel catfish on an intensive basis.

3. Stocking densities ranging from 175 to 500 fish per m^3 of cage were tested. The density of 500 fish per m^3 was considered to be within optimum range for raising fingerlings to 0.8 lb. average per fish.

4. At a density of 500 fish per m^3 of cage, channel catfish were grown from 0.43 to 0.83 lb. per fish in 40 days; this represents an average gain of 0.01 lb. of fish per day, and an increase of 4.94 lb. per cage per day. A total of 1.34 lb. of feed was required to produce 1.0 lb. of fish. The highest standing crop attained was 421 lb.

5. Cage positions relative to other cages and to exposure to wind-induced water currents in open water were found to have an effect on production of fish in those cages. Net gain was highest and feed conversion was lowest in cages positioned to received the highest number of water exchanges per unit of time.

6. Mesh size was found to be a significant factor in fish production in cages. Production in cages enclosed with 0.25-inch mesh hardware cloth was concluded to be inferior to production in cages of 0.50-inch mesh in total net weight increase, average fish size at harvest and per cent survival.

7. A major limiting factor in cage culture of channel catfish in ponds was considered to be rate of water replacement in the cages.

8. In all suspended cage experiments in 1967 and 1968, a net total of 10,121 lb. of fish were produced with 12,713 lb. of feed for a feed conversion of 1.25. The lowest feed conversion obtained in all experiments was 1.03 and ranged from 0.97 to 1.09 between three replications of fish stocked at 300 density per m^3 of cage (cages were 2.89 m^3 stocked with 867 fish per cage).

9. Cages of 2- x 2-inch pine frame and galvanized hardware cloth were constructed for approximately $18 per m^3 including labor; most were satisfactory for three years of culture with only minor repair after the second year. Both the wooden frames and hardware cloth were undesirable in certain aspects as cage materials.

10. A net of approximately 2,000 lb. of channel catfish per acre of pond were produced in cages in each year 1967 and 1968. In addition, another 200-400-net lb. of fishes were produced in the open water of the same pond each year.

11. In some experiments, channel catfish in cages suspended in ponds were fatally affected by the effects of low oxygen-high carbon dioxide concentrations, whereas channel catfish, largemouth bass and other fishes in open water outside the cages did not appear affected.

12. Observations indicate that bacterial diseases, such as columnaris disease, may be a major limiting factor to culture of channel catfish in cages suspended in ponds.

LITERATURE CITED

Gribanov, L. V., A. N. Korneev and L. A. Korneeva. 1968. Use of thermal waters for commercial production of carps in floats in the U.S.S.R. Proc. World Symposium Warm Water Pond Fish Cult. (1966), FAO Fish. Rept. 44 (5) : 218-226.

Kuronuma, K. 1968. "Carp culture in floating net cages in lakes." New systems and new fishes for culture in the Far East. Proc. World Symposium Warm Water Pond Fish Cult. (1966), FAO Fish. Rept. 44 (5) : 123-142.

Prather, E. E. and H. S. Swingle. 1960. Preliminary results of the production and spawning of white catfish in ponds. Proc. Fourteenth Ann. Conf. Southeast. Assoc. Game and Fish Commrs. 14 : 143-145.

Schmittou, H. R. 1969. Intensive culture of channel catfish, *Ictalurus punctatus* (Rafinesque), in cages suspended in ponds. Unpublished Ph.D. Dissertion. Auburn University, Auburn, Alabama. 70 pp.

Steel, R. G. D. and J. H. Torrie. 1960. Principles and procedures of statistics with special reference to the biological sciences. McGraw-Hill Book Co., Inc., New York, Torento, London. 481 pp.

Thiemmedh, J. (1961). Notes on Pangasius culture. Proc. Ninth Pacific Sci. Congress. (1957), 10 : 80-83.

Vass, K. R. and M. Sachlan. 1957. Cultivation of common carp in running water in West Java. Proc. Indo-Pacific Fish Coun., 6th session (1956), Sections II and III : 187-196.

STOMACH CONTENT ANALYSIS OF WHITE BASS (Roccus chrysops) IN BEAVER RESERVOIR, ARKANSAS

By LARRY OLMSTED and RAJ V. KILAMBI

University of Arkansas, Department of Zoology
Fayetteville, Arkansas

ABSTRACT

Qualitative and quantitative analyses of stomach contents of 263 white bass (*Roccus chrysops*) taken from Beaver Reservoir and its tributaries between February 1, 1969 and June 30, 1969 are reported. Fish are classified as pre, mid, and post-spawners based on their migrations into and out of the spawning areas. Stomach contents of white bass are enumerated by frequency occurrence, volumetric and gravimetric methods. Significant differences in the food habits were found between the different periods.

INTRODUCTION

Knowledge of the food habits of fishes, as individuals or as groups, is vital to reservoir understanding (Jenkins, 1964). Martin (1966), work-